The Effect of Temperature on the Induction Time of a Stabilized Oil

Greg Reynhout*
Kalsec, Inc., Kalamazoo, Michigan 49005

Soybean oil was fortified with the antioxidants BHT (butylated hydroxytoluene), BHA (butylated hydroxyanisole), TBHQ (tertiary butylhydroquinone), rosemary extract (Herbalox® Seasoning) and tocopherol. Induction times were determined against a control on each sample in a Metrohm Rancimat over a temperature range of 80°C to 180°C. A linear effect of the data was obtained when the log of induction time was plotted against temperature. The Metrohm Rancimat was found to be capable of determining induction times within the range of 0.5 to 70 hr.

KEY WORDS: Induction time, oxidation, shelf-life.

The oxidation of lipids in food systems is one of the more important reactions that can cause deterioration in the quality of food products. To better understand the impact of lipid stabilization on product shelf-life, several accelerated methods have been developed to test the resistance of lipids to oxidation. All these accelerated methods involve the use of elevated temperatures because it is known that the rate of the reaction is exponentially related to temperature. In work illustrating the effect of temperature on antioxidant-stabilized lipids, doubt in the accuracy of the high-temperature tests as they relate to lower temperature shelf-life conditions has been reported (1,2).

With a Metrohm Rancimat (Herisau, Switzerland) to accelerate and measure lipid oxidation by induction time, the effect of a range of temperatures was measured on stabilized lipids. The temperature range imposed its own limits on the minimum and maximum temperature at which induction times can be measured.

MATERIALS AND METHODS

Induction times were obtained from a Metrohm Rancimat, Model 679, capable of performing at a temperature range of 50–220°C. Soybean oil was stabilized with 0.02% (w/w) BHT (butylated hydroxytoluene), BHA (butylated hydroxyanisole), TBHQ (tertiary butylhydroquinone) and with 0.04% (w/w) tocopherol (GT-1 obtained from Eastman Chemical, Rochester, NY) and rosemary extract (Herbalox® Seasoning Type O from Kalsec, Inc., Kalamazoo, MI). The synthetic antioxidants were added at their maximum legal limit (200 ppm). As the tocopherol and rosemary extract preparations both contained vegetable oil as a carrier, they were added to provide approximately the same protection level as the synthetics. All samples were run

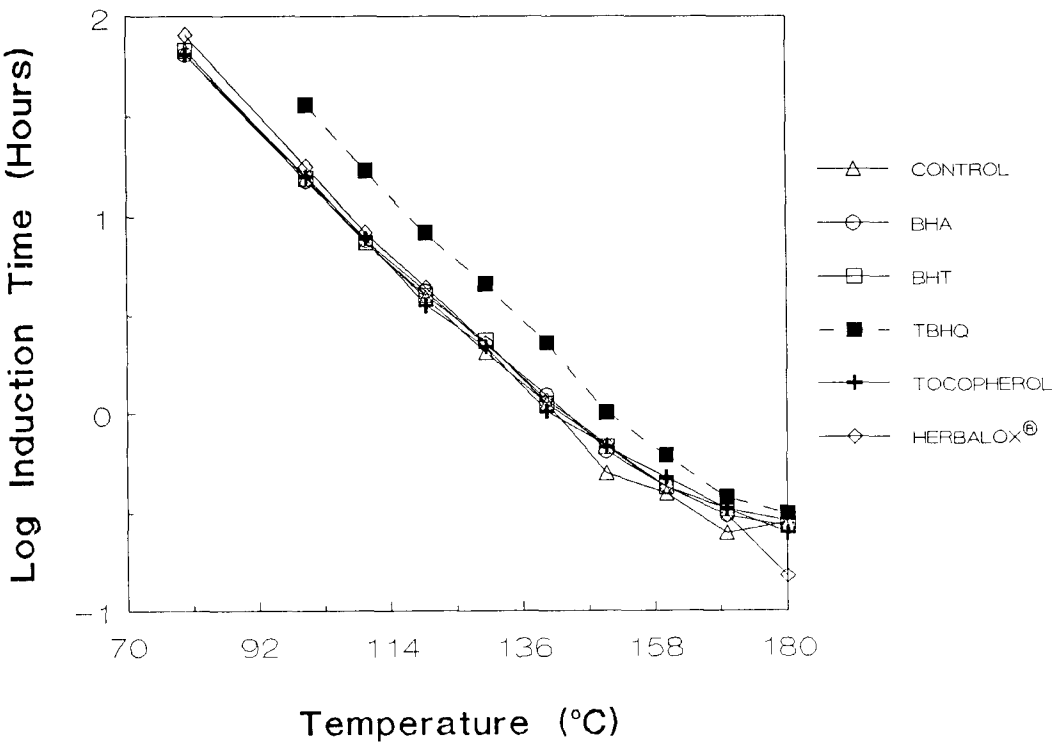

FIG. 1. Linear relationship of induction time.

*To whom correspondence should be addressed at Kalsec, Inc., P.O. Box 511, Kalamazoo, Michigan 49005.

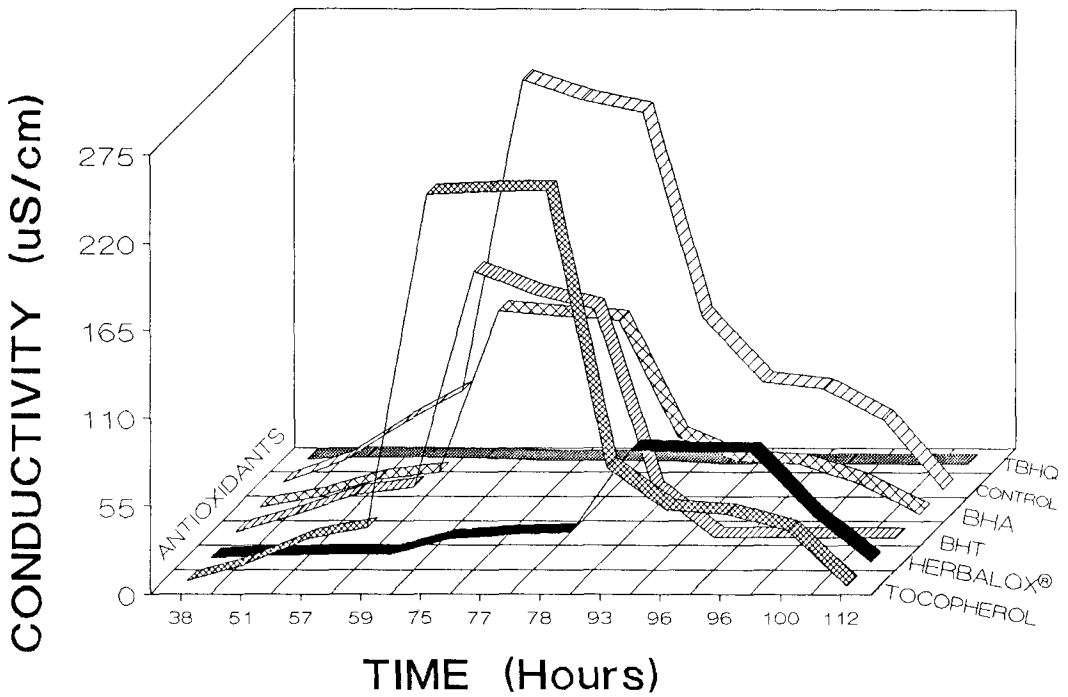

FIG. 2. Conductivity *vs* time at 80° Celsius.

against a control at a sample weight of 2.0 g and an air flow of 18 L/hr.

RESULTS AND DISCUSSION

Induction times were obtained from the Rancimat over a temperature range of 80°C to 180°C. As expected, the induction time increased with decreasing temperature, and when the induction time was expressed on a logarithmic scale against temperature (Fig. 1), a straight line was obtained for all antioxidant systems. This logarithmic relationship even held for the highly volatile antioxidants at temperatures past where they were considered effective (3).

Only at the highest temperature did data appear to begin to level off. This may be due to the rate of oxidation being limited by the mechanism of degradation. For example, at a certain temperature the free-radical chain-reaction mechanism responsible for the formation of volatile acids, which are measured conductometrically by the Rancimat, has a maximum reaction time that cannot be increased by increasing temperature. At these high temperatures, the accuracy of duplicate assays at induction times under 0.5 hr was typically no longer within 10% of each other. Induction times shorter than 0.5 hr were considered outside the capability of the Rancimat.

At the other end of the spectrum, it was found at the longer induction times that a self-limiting point was reached due to water evaporation in the conductivity cells. As shown in Figure 2, the maximum conductivity achieved was at approximately 70 hr. After this point, the conductivity declines to zero. Therefore, induction times greater than 70 hr, *e.g.* TBHQ at 80°C, could not be accurately determined. The indicated parameters for induction times between 0.5 and 70 hr show that temperature does not change the mechanism of oxidation within the temperature range of this method.

Though the relationship of each system to the control may change over the effective temperature range in this method, each system itself remains linear. If one can assume that this relationship will hold outside the effective temperature range of this method, then it can be used to predict oxidative stability at lower temperatures. Even so, we should not fall into the trap of thinking such extrapolated data would correlate with actual room temperature data to provide an exact shelf-life period. Any data can only be accepted as the expected induction time for that system under the same conditions at a lower temperature. An attempt to correlate this induction time to a shelf-life period for a food system would not take into account the effect of other data determining elements such as interactions within the complete food system.

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